ISSN 1392-3196 / e-ISSN 2335-8947
Zemdirbyste-Agriculture, vol. 108, No. 1 (2021), p. 57–62
DOI 10.13080/z-a.2021.108.008

Evaluation of the biological-economic and biochemical traits of promising *Ribes nigrum* hybrids in Estonia

Ave KIKAS, Peeter LAURSON, Asta-Virve LIBEK

Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences
Polli, Viljandi distr., Estonia
E-mail: ave.kikas@emu.ee

Abstract

The evaluation of promising hybrids of blackcurrant (*Ribes nigrum* L.) was carried out in 2016–2018 in South-Estonia at Polli Horticultural Research Centre of the Estonian University of Life Sciences. The objective of the Estonian blackcurrant breeding programme is to produce cultivars that are winter hardy, resistant to gall mite (*Cecidophyopsis ribis* Westw.) and gooseberry mildew (*Sphaerotheca mors-uvae* (Schw.) Berk.), well suited to machine harvesting, with good yield and quality of fruits. The evaluation plot was established in the autumn of 2014. Twenty-four blackcurrant promising hybrids from the Estonian blackcurrant breeding programme and a new Estonian cultivar 'Mairi' as the standard were evaluated for beginning of flowering and fruit ripening (expressed in growing degree-days, GDD), winter hardiness, resistance to diseases and pests (expressed in scores 1–9), number of fruits per cluster, yield (kg per bush), weight of fruit and content of the soluble solids (°Brix). Fruits were analysed for titratable acids, ascorbic acid, anthocyanins and polyphenols. The evaluation revealed the best black-fruited genotypes to be Nos 3-08-1 ('Ben Alder' × 'Titania'), 7-08-1, 7-08-2 ('Intercontinental' × 'Pamyat Vavilova') and 15-09-1 ('Asker' free pollination), and the green-fruited genotype No. 8-09-3 ('Öjebyn' × 'Mairi'). All these genotypes are winter hardy and visually resistant to gall mite and gooseberry mildew. The first four produced good yields and large fruits.

Key words: anthracnose, blackcurrant genotypes, fruit weight, winter hardiness, yield.

Introduction

Blackcurrant (*Ribes nigrum* L.) is an important soft fruit crop cultivated commercially in moderate-temperature regions of the world (Brennan, 2008; Sasnauskas et al., 2009; Pluta, Żurawicz, 2014; Woznicki et al., 2015; Strautiņa et al., 2020). Blackcurrant breeding is carried out in different countries; classical breeding is integrated with new techniques and breeding methods (Mažeikienė et al., 2019; Stanys et al., 2019; Jarret et al., 2020).

In Estonia, blackcurrant breeding has a long tradition dating back to the beginning of last century, stimulated recently in 2000 with financial support from the government. The aim of the breeding programme is to produce cultivars that are winter hardy, resistant to gall mite (*Cecidophyopsis ribis* Westw.) and gooseberry mildew (*Sphaerotheca mors-uvae* (Schw.) Berk.), well suited to machine harvesting, with good yield and fruit quality. These traits are also important in other blackcurrant breeding programmes (Sasnauskas et al., 2009; 2013; Masny et al., 2018). In the 21st century, the blackcurrant cultivars 'Varmas' (2003), 'Ats', 'Almo', 'Elo', 'Karri' (2008), 'Elmar' (2018), 'Asker' and 'Mairi' (2019) have been developed and registered under the breeding programme. 'Varmas', 'Elo', 'Karri' and 'Mairi' are very good dessert cultivars (Kikas et al., 2017; 2019); the cultivar 'Asker' has a high and stable ascorbic acid content (Kaldmäe et al., 2013; Kikas et al., 2017).

The purpose of this study was to evaluate 24 promising hybrids of blackcurrant for biological-economic properties: beginning of flowering and fruit ripening, winter hardiness, disease and pest resistance, flower and young fruit drop, yield, number of fruits per cluster, and biochemical properties of the fruit and select potential cultivars.

Materials and methods

The evaluation of promising blackcurrant (*Ribes nigrum* L.) hybrids was carried out in 2016–2018 in South-Estonia at Polli Horticultural Research Centre (58°7′26″ N, 25°32′43″ E) of the Estonian University of Life Sciences Institute of Agricultural and Environmental Sciences. The evaluation plot was established in the autumn of 2014 with one-year old plants. Bushes were in plots of 3 × 0.8 m with three replicates of each cultivar.

Please use the following format when citing the article:
Kikas A., Laurson P., Libek A.-V. 2021. Evaluation of the biological-economic and biochemical traits of promising *Ribes nigrum* hybrids in Estonia. Zemdirbyste-Agriculture, 108 (1): 57–62. DOI 10.13080/z-a.2021.108.008

For three consecutive years, 24 promising hybrids from the Estonian blackcurrant breeding programme and the new cultivar 'Mairi' as the standard were evaluated (Table 1).

Table 1. The pedigree of the tested blackcurrant genotypes

Genotype No.	Parentage	Colour of fruit
'Mairi'	Öjebyn × Kantata 50	black
6-09-1	Ben Sarek × Asker	black
10-09-1	Mairi × Öjebyn	green
10-09-2	Mairi × Öjebyn	black
8-09-3	Öjebyn × Mairi	green
9-09-1	Asker × Karri	black
1-08-2	Titania × Ben Sarek	black
1-08-1	Titania × Ben Sarek	black
3-08-1	Ben Alder × Titania	black
7-08-1	Intercontinental × Pamyat Vavilova	black
7-09-1	Asker × Ben Sarek	black
8-09-1	Öjebyn × Mairi	black
7-08-3	Intercontinental × Pamyat Vavilova	black
7-08-2	Intercontinental × Pamyat Vavilova	black
11-09-3	Mairi × Asker	black
11-09-4	Mairi × Asker	black
12-09-1	Ben Sarek × Karri	black
12-09-2	Ben Sarek × Karri	black
13-09-2	Mairi × Ben Sarek	black
13-09-1	Mairi × Ben Sarek	black
15-09-1	Asker free pollination	black
8-08.3	Titania × Ben Connan	black
8-08-9	Titania × Ben Connan	black
5-09-2	Mairi × Ben Connan	black
5-09-1	Mairi × Ben Connan	black

Each spring, 300 kg ha^{-1} of the complex fertilizer Cropcare 6-14-23 (Kemira OY) was applied along the rows. The rows were mulched with milled peat, and inter-row spaces were grown to grasses and mown four times during the summer. The plantation was set up on a moderately heavy, loamy soil with good drought resistance, so no irrigation system was required. No pesticides were used in the plantation.

The following characteristics of the blackcurrant genotypes were recorded: the beginning of flowering (10% of flowers fully open), the beginning of fruit ripening (10% of fruits with full colour). Based on this, the growing degree-days (GDD) to anthesis and start of ripening were calculated according to equation (McMaster, Wilhelm, 1997; Aydin et al., 2019):

$$GDD = (T_{max} + T_{min}/2) - T_{base},$$

where T_{max} and T_{min} are daily max and min temperatures, T_{base} is base temperature. A base temperature of 5°C was used (Dalton, Hummer, 2010). This is the beginning point of the GDD calculation.

The following parameters were recorded: flower and young fruit drop during full bloom, the number of flowers in 20 random clusters per bush and the number of fruits remaining on the clusters three weeks after flowering. Based on the data collected, the percentage of flower and young fruit drop was calculated, and yield (kg bush^{-1}) and fruit weight (calculated by 100 berry weight, g) were recorded.

Winter damage was evaluated on a scale of 1–9 points each spring during the intensive growth of leaves. Also, damage by anthracnose (*Drepanopeziza ribis* Kleb.), gall mite (scores 1–9: 1 – no visible symptoms of infection, 9 – more than 75% damaged buds) and gooseberry mildew (scores 1–9: 1 – no visible symptoms of infection, 9 – more than 75% damaged leaves) was recorded.

The data on average air temperature and precipitation per ten days for May, June and July of the testing years are given in Table 2.

The winter of 2015–2016 was favourable for the wintering of blackcurrant genotypes, and damage was absent. The first ten-day period of May was very warm with no precipitation. The spring and summer of 2017 were quite cool. In 2017–2018, winter temperature after quite a warm period fell to −20°C. The summer of 2018 was very dry and hot.

Table 2. Average air temperature and amount of precipitation during May to July in 2016, 2017 and 2018

Month	Ten-day period	Average air temperature per ten days °C			Precipitation mm		
		2016	2017	2018	2016	2017	2018
May	I	14.0	6.7	11.8	0.0	3.3	17.4
	II	12.4	10.3	16.3	20.4	0.6	8.0
	III	16.0	13.5	17.2	0.0	9.9	0.0
June	I	14.1	12.3	14.0	5.0	21.1	12.1
	II	14.3	15.7	17.4	107.6	15.6	17.1
	III	19.7	13.8	15.2	18.1	24.2	31.4
July	I	16.8	14.4	15.7	48.1	31.8	15.1
	II	17.3	15.4	21.7	18.6	42.5	2.5
	III	19.8	16.9	22.9	8.5	5.1	22.2

In the juice, the content of soluble solids (%) was determined with a refractometer ABBE WAY-1S (Optic Ivymen System, Spain), titratable acids (%, citric acid equivalent) – by titration with 0.1 M NaOH and ascorbic acid (mg 100 g^{-1} fresh weight – FW) – according to T05-HPLC method (Williams et al., 1973). The content of total polyphenols (mg 100 g^{-1} FW, chlorogenic acid equivalent) and total anthocyanins (mg 100 g^{-1} FW, cyanidin-3-glucoside equivalent) were quantified using a Shimadzu Nexera X2 UHPLC-DAD System (Japan). Determination of ascorbic acid content was performed by the Tartu Laboratory of the Estonian Health Board. The remaining analyses were performed by the Biochemistry Laboratory of Polli Horticultural Research Center of the Estonian University of Life Sciences.

The results were analysed by a two-way analysis of variance (ANOVA) and correlation analyses. To evaluate the effect of genotypes, the least significant differences $LSD_{0.05}$ or $LSD_{0.01}$ were calculated; different letters in tables mark significant differences at $p \leq 0.05$ or $p \leq 0.01$.

Results and discussion

Phenological traits. Weather conditions, in particular temperature, are an important factor for biological development and yield formation of plants. Plant phenology is better measured in growing degree-days (GDD, °C-day) compared to other approaches such as time of year (McMaster, Wilhelm, 1997). The GDD required to start blackcurrant flowering depends on both growth conditions and genotype. The lowest GDD was in the cool spring in 2017 with an average for genotypes of only 81 GDD. In 2016 and 2018, it did not differ significantly from the genotypes averaging 127 and 139 GDD, respectively (Table 3). In 2017, the amount of GDD required for flowering was the smallest with flowering about ten days later than in 2016 and 2018.

Table 3. The growing degree-days (GDD) to the beginning of flowering and fruit ripening of blackcurrant genotypes

Genotype No.	GDD to flowering				GDD to fruit ripening			
	2016	2017	2018	average	2016	2017	2018	average
‘Mairi’	98	64	115	92 ± 25.9 b	695	705	732	711 ± 19.2 b
6-09-1	117	100	150	123 ± 25.4 ab	800	728	792	773 ± 39.6 ab
10-09-1	107	75	141	108 ± 33.3 ab	774	716	743	744 ± 29.2 b
10-09-2	98	100	141	113 ± 24.5 ab	800	728	778	769 ± 37.1 ab
8-09-3	98	87	141	109 ± 28.9 ab	738	716	806	753 ± 46.7 b
9-09-1	107	87	141	112 ± 27.5 ab	786	728	765	759 ± 29.4 ab
1-08-2	155	87	160	134 ± 40.6 a	957	716	792	821 ± 121.1 ab
1-08-1	141	87	150	126 ± 34.1 ab	957	728	778	821 ± 120.3 ab
3-08-1	147	75	141	121 ± 40.9 ab	990	684	743	806 ± 162.1 ab
7-08-1	147	67	134	116 ± 42.9 ab	990	728	806	841 ± 134.6 a
7-09-1	172	87	141	134 ± 43.3 a	957	728	806	830 ± 116.4 ab
8-09-1	177	67	134	126 ± 55.3 ab	889	705	806	800 ± 91.8 ab
7-08-3	182	75	134	130 ± 53.6 a	990	739	778	836 ± 134.9 ab
7-08-2	182	67	115	122 ± 57.4 ab	973	739	792	834 ± 122.6 ab
11-09-3	98	67	134	100 ± 33.6 ab	914	716	743	791 ± 107.1 ab
11-09-4	117	87	141	115 ± 27.3 ab	900	705	743	783 ± 103.5 ab
12-09-1	127	87	134	116 ± 25.6 ab	957	739	806	834 ± 111.6 ab
12-09-2	90	75	141	102 ± 35.0 ab	914	739	754	802 ± 96.7 ab
13-09-2	127	75	134	112 ± 32.5 ab	941	705	792	813 ± 119.4 ab
13-09-1	90	87	141	106 ± 30.7 ab	900	764	843	836 ± 68.5 ab
15-09-1	136	87	141	121 ± 30.0 ab	914	684	792	797 ± 114.7 ab
8-08-3	141	87	141	123 ± 31.2 ab	941	716	792	816 ± 114.7 ab
8-08-9	136	100	160	132 ± 29.8 a	941	764	818	841 ± 90.8 a
5-09-2	90	64	125	93 ± 30.2 b	973	752	830	851 ± 112.0 a
5-09-1	98	75	150	108 ± 38.7 ab	927	728	754	803 ± 108.3 ab
Average for genotypes	127	81	139	116 ± 30.6	901	724	783	803 ± 90.1

Note. In columns, different letters mark significant differences at $p \leq 0.05$.

According to Hummer and Dale (2010), currants need 160–200 GDD to start flowering, but in our experiment, it was much lower, especially in 2017. This may be due to the genotype differences (Krüger et al., 2011; Pluta, Pruski, 2012) and agroclimatic conditions (Pedersen, 2007; Yang et al., 2010), which play an important role in the development of blackcurrant plants. Cultivar ‘Mairi’ and genotype No. 5-09-2 needed the least GDD for flowering, 92 and 93 GDD, respectively, while genotypes Nos 1-08-2, 7-09-1, 7-08-3 and 8-08-9 required the most GDD (Table 2).

To start ripening, the fruits needed the highest amount of GDD in 2016 and the least amount in 2017, with a genotype average of 901 GDD and 724 GDD, respectively. The least amount of GDD was needed by the cultivar ‘Mairi’ and genotypes Nos 10-09-1 and 8-09-3 for the start of fruit ripening, and the differences between GDD over the years were relatively small. The genotypes Nos 7-08-1, 8-08-9 and 5-09-2 needed the most GDD for the beginning of fruit ripening, and the differences between GDD were relatively large between years. The early cultivar ‘Mairi’ and Nos 10-09-1 and 8-09-3 were shown to be early maturity genotypes, and Nos 7-08-1, 8-08-9 and 5-09-2 were late maturity genotypes (Kikas et al., 2019). Winter damage occurred only in 2018 for the genotypes Nos 11-09-3 and 12-09-1, all with 7 points. The bushes recovered well.

Physiological traits. During the experimental years, flower and young fruit drop was not large, and the differences between the years were small with genotype means of 15.5, 10.5 and 11.0 %, respectively. It was the highest in the Nos 9-09-1 (22.5%) and 1-08-1 (22.7%), but less than 20% in the remaining genotypes (Table 4).

There was a positive correlation (r = 0.56) between the amount of GDD required for flowering and the onset of fruiting. Correlation analysis revealed only a weak positive relationship (r = 0.14) between flower and young fruit drop and GDD to flowering. Clusters had the most fruits in 2016, 2018 and the least in 2017, the amount of GDD required for flowering, and fruit ripening was the smallest with 6.8, 6.2 and 5.5, respectively. The longest clusters were on genotypes Nos 8-09-1 and 11-09-4 with 7.8 and 7.7 fruits, respectively. One of the parents of both genotypes is cultivar ‘Mairi’, which also has relatively long clusters. There was a weak negative relationship (r = −0.15) between the number of fruits per cluster and flower and young fruit drop.

Economic traits. The average yield of genotypes was the highest in 2018 and the lowest in 2016 with 1.1 and 2.4 kg bush^{-1}, respectively. This is also logical, as bushes were still young in 2016, the genotypes Nos 3-08-1, 7-08-3, 7-08-2, 7-08-1 and 15-09-1 produced good yields in the first testing year with 2, 1.8, 1.6, 1.5 and 1.5 kg bush^{-1}, respectively. The yield of ‘Mairi’ in 2016 was 1.5 kg bush^{-1}. On average over the test years, the highest yield was from No. 7-08-1 (2.5 kg bush^{-1}), followed by Nos 3-08-1 and 7-08-2 (2.3 kg bush^{-1}), and Nos 7-08-3 and 15-09-1 (2.1 kg bush^{-1}) (Table 4). The yield of ‘Mairi’ was 2.1 kg bush^{-1}.

One of the parents of genotypes Nos 7-08-1, 7-08-2 and 7-08-3 was cultivar ‘Pamyat Vavilova’, which has proved to be a good and stable yielding cultivar in

Table 4. The physiological traits of blackcurrant genotypes

Genotype No.	Yield kg bush^{-1}	Number of fruits per cluster	Fruit weight g	Flower and young fruit drop %	Damage by anthracnose[1]
'Mairi'	2.1 ± 0.87 ab	6.7 ± 1.62 ab	1.5 ± 0.36 b	11.3 ± 12.4 b	2.7 cd
6-09-1	1.7 ± 1.0 bc	5.9 ± 1.15 b	1.2 ± 0.06 bd	8.6 ± 1.75 b	2.7 cd
10-09-1	1.4 ± 0.45 bc	6.3 ± 0.7 ab	0.7 ± 0.06 f	14.8 ± 7.3 ab	4.3 ab
10-09-2	1.6 ± 1.10 bc	7.3 ± 0.92 ab	0.9 ± 0.10 e	13 ± 6.8 b	2.7 cd
8-09-3	1.3 ± 0.64 c	5.6 ± 0.26 b	1.0 ± 010 e	7.3 ± 5.1 b	3.3 bc
9-09-1	1.6 ± 0.49 bc	6.5 ± 0.51 ab	1.4 ± 0.15 bc	22.5 ± 16.0 a	4.3 ab
1-08-2	2.0 ± 0.67 ab	4.9 ± 1.2 b	1.3 ± 0.17 c	16.6 ± 3.3 ab	2.7 cd
1-08-1	1.5 ± 0.76 bc	6.2 ± 0.30 ab	1.1 ± 0.10 d	22.7 ± 5.4 a	3.7 b
3-08-1	2.3 ± 0.61 ab	5.2 ± 0.97 b	1.4 ± 0.26 bc	18 ± 1.6 ab	4.3 ab
7-08-1	2.5 ± 1.20 a	6.3 ± 1.60 ab	1.5 ± 0.23 b	11 ± 2.4 b	4.3 ab
7-09-1	2.0 ± 0.70 ab	5.7 ± 1.03 b	1.5 ± 0.15 b	8.8 ± 5.8 b	2.7 cd
8-09-1	1.5 ± 0.66 bc	7.8 ± 0.99 a	1.1 ± 015 c	5.3 ± 1.5 b	2.3 d
7-08-3	2.1 ± 0.50 ab	7.1 ± 1.87 ab	1.4 ± 0.10 bc	7.3 ± 3.5 b	4.3 ab
7-08-2	2.3 ± 0.76 ab	6.9 ± 1.17 ab	1.6 ± 0.20 ab	8.7 ± 3.1 b	4.3 ab
11-09-3	1.5 ± 0.9 bc	6.3 ± 0.46 ab	1.7 ± 0.06 a	14 ± 4.8 ab	3 c
11-09-4	2.0 ± 1.20 ab	7.7 ± 0.15 a	1.1 ± 0.15 d	8.9 ± 5.0 b	3 c
12-09-1	1.9 ± 0.61 b	5.7 ± 0.76 b	1.4 ± 0.02 bc	11.4 ± 9.5 b	3 c
12-09-2	1.4 ± 0.53 bc	5.7 ± 0.96 b	1.4 ± 0.21 bc	13.6 ± 8.9 ab	3.3 bc
13-09-2	1.7 ± 0.96 bc	6.8 ± 0.42 ab	1.2 ± 0.15 cd	7.7 ± 3.0 b	3.7 b
13-09-1	1.9 ± 1.20 b	5.7 ± 1.08 b	1.3 ± 0.06 c	9 ± 5.9 b	3 c
15-09-1	2.1 ± 0.75 ab	6.3 ± 0.70 ab	1.5 ± 0.06 b	11.8 ± 7.3 b	3.3 bc
8-08.3	1.6 ± 0.42 bc	5.7 ± 1.03 b	1.1 ± 0.06 d	15.5 ± 6.0 ab	3.7 b
8-08-9	1.1 ± 0.44 c	5.0 ± 0.55 b	1.1 ± 0.10 d	17.8 ± 6.4 ab	3.7 b
5-09-2	0.8 ± 0.30 c	4.6 ± 0.20 b	1.1 ± 0.12 d	11.3 ± 8.3 b	4.7 a
5-09-1	1.8 ± 0.55 bc	6.0 ± 0.55 b	1.2 ± 015 cd	11.6 ± 2.4 b	3 c

Note. [1] – scores 1–9: 1 – no visible symptoms of infection, 9 – more than 75% damaged leaves; data are mean ± SD across all years; in columns, different letters mark significant differences at $p \leq 0.05$.

Estonia (Kikas et al., 2019), Russia and Belorussia (Bohonova, 2004; Dmitriyeva, Korovin, 2008). Yield of genotypes was negatively related to GDD to beginning of ripening ($r = -0.34$) and flower and young fruit drop ($r = -0.22$). In terms of genotype averages, fruits were the smallest in 2017 (1.1 g), when the amount of GDD required for flowering was also the smallest; in 2016 and 2018 average fruit weight was similar (1.3 g). On average for the experimental years, the largest fruits were from the Nos 11-09-3 (1.7 g) and 7-08-2 (1.6 g), followed by genotypes Nos 7-08-1, 7-09-1, 15-09-1 and cultivar 'Mairi' (all 1.5 g).

In previous experiments, cultivar 'Mairi' produced large fruit. The large-fruited 'Intercontinental' is the mother cultivar of genotypes Nos 7-08-1 and 7-08-2. These genotypes outyielded their mother cultivar. Fruit size is at the same level as that of the 'Intercontinental' but larger than that of the father 'Pamyat Vavilova' (Sasnauskas et al., 2009; Kikas et al., 2019). Genotype No. 3-08-1 outyielded the parental cultivars 'Ben Alder' and 'Titania' – the fruit size was larger than that of the parental cultivars (Kaldmäe et al., 2013; Pluta, Żurawicz, 2014; Mazeikiene et al., 2017 b). Genotype No. 15-09-1 has higher yield and larger fruits than that of the mother cultivar 'Asker' (Kikas et al., 2019). There was a mean positive relationship ($r = 0.29$ and $r = 0.32$) between fruit weight and yield and fruit weight and GDD to fruit ripening, respectively. Experiments carried out elsewhere have produced different results. In Serbia, a weak positive correlation was found between fruit yield and weight (Rakonjac et al., 2015), and in Poland, a strong negative correlation was found (Madry et al., 2005).

Phytopathological and entomological traits. An important factor in the development of new cultivars is their resistance to diseases and pests, for blackcurrant cultivars resistance to gall mite, anthracnose and gooseberry mildew. Damage by the gall mite (*Cecidophyopsis ribis* Westw.) is very dangerous, as it can limit yield severely and is a biological vector blackcurrant reversion virus (BRV) (Mazeikiene et al., 2017 a; Mažeikienė et al., 2019). Gall mite occurred (2 score) only in the last testing year in genotype No. 6-09-1, and gooseberry mildew (*Sphaerotheca mors-uvae* Schw. Berk.) – only in the genotypes Nos 8-09-1 and 11-09-3 (2 and 3 scores, respectively). The damage by anthracnose (*Drepanopeziza ribis* Kleb.) was the weakest in 2016. On average throughout the years, damage by anthracnose was the weakest in No. 8-09-1 (2.3 scores) and the strongest in No. 5-09-2 (4.7 scores) (Table 4).

Chemical content of fruits of the best genotypes. Fruits of cultivar 'Mairi' had the highest soluble solids content (18.7), followed by genotypes Nos 8-09-3 and 3-08-1 (Table 5).

Table 5. The content of soluble solids, organic acids, ascorbic acid, anthocyanins and polyphenols in the fruits of blackcurrant genotypes

Genotype No.	SS[1] Brix°	TA[1] %	AA[2] mg 100 g^{-1}	AC mg 100 g^{-1}	PP mg 100 g^{-1}
'Mairi'	18.7 ± 0.66 a	2.3 ± 0.21 d	–	194 ± 57.3 b	304 ± 74.2 b
3-08-1	15.9 ± 1.51 b	2.9 ± 0.0 bc	127	147 ± 20.3 d	235 ± 56.6 dc
7-08-1	14.7 ± 1.2 d	3.0 ± 0.21 b	137	164*	228*
7-08-2	14.5 ± 1.25 c	2.9 ± 0.26 bc	89	175 ± 4.9 c	268 ± 36.1 c
8-09-3	15.9 ± 0.9 b	2.8 ± 0.3 c	99	–	54.7 ± 10.6 c
15-09-1	14.8 ± 1.22 d	3.2 ± 0.15 a	208	273 ± 9.9 a	400 ± 13.4 a

Note. SS – soluble solids, TA – titratable acids, AA – ascorbic acid, AC – anthocyanins, PP – polyphenols; [1] – data are mean ± SD across all years, [2] – one-year data; in columns, different letters mark significant differences at $p \leq 0.01$.

Titratable acid content was the lowest in the fruit of cultivar 'Mairi' and the highest of genotype No. 15-09-1. The content of ascorbic acid, anthocyanins and polyphenols was the highest in the fruits of genotype No. 15-09-1. The content of ascorbic acid was at the same level as that of the mother cultivar 'Asker' (Kaldmäe et al., 2013). Fruits of 'Mairi' contain 121 mg 100 g^{-1} ascorbic acid (Kikas et al., 2017). Fruits of the green-fruited genotype No. 8-09-3 did not contain anthocyanins, and the content of ascorbic acid and polyphenols was relatively low.

Conclusion

1. The experiment revealed the best blackcurrant genotypes to be Nos: 3-08-1 ('Ben Alder' × 'Titania'), 7-08-1, 7-08-2 ('Intercontinental' × 'Pamyat Vavilova') and 15-09-1 ('Asker' free pollination), and the green-fruited No. 8-09-3 ('Öjebyn' × 'Mairi'). All these genotypes had higher or equal yield, number of fruits per cluster, weight of fruit compared to the standard cultivar 'Mairi'. These were all winter hardy and visually resistant to gall mite (*Cecidophyopsis ribis* Westw.) and gooseberry mildew (*Sphaerotheca mors-uvae* (Schw.) Berk.).

2. The growing degree-days (GDD) required to start blackcurrant flowering and fruit ripening depended on both growing conditions and the genotype.

3. Genotype No. 3-08-1 was mid-ripening, produced good yield (2.3 kg $bush^{-1}$) and large fruit (1.4g). It outyielded the parental cultivars 'Ben Alder' and 'Titania', but the fruits were larger than those of the parental cultivars.

4. Genotypes Nos 7-08-1 and 7-08-2 were mid- to late-ripening, produced good yield (2.5 and 2.3 kg $bush^{-1}$, respectively) and large fruit (1.5 and 1.6 g, respectively). They outyielded the mother cultivar 'Intercontinental'; the size of the fruit was at the same level as that of the 'Intercontinental' and larger than that of the father cultivar 'Pamyat Vavilova'. Flower and young fruit drop was small.

5. Genotype No. 15-09-1 was mid-ripening, produced good yield (2.1 kg $bush^{-1}$) and large fruit (1.5 g). Flower and young fruit drop was small. The content of ascorbic acid (208 mg 100 g^{-1}) was at the same level as that of the mother cultivar 'Asker', the amount of anthocyanins (273 mg 100 g^{-1}) and polyphenols (400 mg 100 g^{-1}) in the fruits was high.

6. No. 8-09-3 was the best of the green-fruited genotypes. It is an early season genotype with average yield. Flower and young fruit drop was small. Farmers like this genotype, as it is good for wine making.

Acknowledgements

The authors want to thank the Estonian Ministry of Rural Affairs for the financial support for National Programme for Plant Breeding from 2009–2019 and 2020–2030.

We thank PlantValor laboratory staff H. Kaldmäe, R. Rätsep and A. Aluvee for performing biochemical analyses, supported by the European Regional Development Fund. The authors are grateful to I. Williams for the English language correction, supported by Institutional Research Funding IUT36-2 of the Estonian Ministry of Education and Research.

Received 28 03 2020
Accepted 04 09 2020

References

Aydin Y., Yücel A., Atilgan A., Tanriverdi Ç. 2019. Determination of growing degree-day (GDD) values: pistachio (*Pistacia vera* L.) case. Series B, Horticulture, LXIII (2): 47–54.

Bohonova M. I. 2004. Peculiarities of growth and fruit bearing of blackcurrant cultivars. Plodovodstvo, 15: 71–74 (in Russian).

Brennan R. M. 2008. Currants and gooseberries. Hancock J. F. (ed.). Temperate fruit crop breeding. Springer, p. 177–196. https://doi.org/10.1007/978-1-4020-6907-9_6

Dalton D. T., Hummer K. E. 2010. *Ribes* bloom phenology: section *Botrycarpum* and *Ribes*. Journal of the American Pomological Society, 64 (3): 140–151.

Dmitriyeva A. M., Korovin K. L. 2008. Results of blackcurrant variety study in Belarus. Plodovodstvo, 20: 157–162 (in Russian).

Hummer K. E., Dale A. 2010. Horticulture of *Ribes*. Forest Pathology, 40: 251–263. https://doi.org/10.1111/j.1439-0329.2010.00657.x

Jarret D., Jennings N., Williams D., Graham J. 2020. Development and use of genetic tools in *Rubus* and *Ribes* breeding at James Hutton Institute/Limited. Acta Horticulturae, 1277: 1–10. https://doi.org/10.17660/ActaHortic.2020.1277.1

Kaldmäe H., Libek A.-V., Arus L., Kikas A. 2013. Genotype and microclimate conditions influence ripening pattern and quality of blackcurrant (*Ribes nigrum* L.) fruit. Zemdirbyste-Agriculture, 100 (2): 167–174. https://doi.org/10.13080/z-a.2013.100.021

Kikas A., Kahu K., Arus L., Kaldmäe H., Rätsep R., Libek A.-V. 2017. Qualitative properties of the fruits of blackcurrant *Ribes nigrum* L. genotypes in conventional and organic cultivation. Proceedings of the Latvian Academy of Sciences. B: Natural, Exact, and Applied Sciences, 71 (3): 190–197. https://doi.org/10.1515/prolas-2017-0032

Kikas A., Laurson P., Libek A.-V. 2019. Evaluation of Belorussian and Estonian blackcurrant *Ribes nigrum* L. cultivars in Estonia. Plodovodstvo, 31: 13–138.

Krüger E., Dietrich H., Hey M., Patz C. 2011. Effects of cultivar, yield, berry weight, temperature and ripening stage on bioactive compounds of black currants. Journal of Applied Botany and Food Quality, 84: 40–46.

Madry W. M., Kozak S., Pluta E., Zurawicz E. 2005. A new approach to sequential yield component analysis (SYCA): application to fruit yield in blackcurrant (*Ribes nigrum* L.). Journal of New Seeds, 7: 85–107. https://doi.org/10.1300/J153v07n01_07

Masny A., Pluta S., Seliga Ł. 2018. Breeding value of selected blackcurrant (*Ribes nigrum* L.) genotypes for early-age fruit yield and its quality. Euphytica, 214 (6): 1–21. https://doi.org/10.1007/s10681-018-2172-9

Mazeikiene I., Bendokas V., Baniulis D., Staniene G., Juskyte A. D., Sasnauskas A., Stanys V., Siksnianas T. 2017 (a). Genetic background of resistance to gall mite in *Ribes* species. Agricultural and Food Science, 26 (2): 110–116. https://doi.org/10.23986/afsci.59410

Mazeikiene I., Stanys V., Juskyte A. D., Sasnauskas A., Siksnianas T. 2017 (b). Blackcurrant varieties 'Aldoniai' and 'Didikai'. Zemdirbyste-Agriculture, 36 (1–2): 7–14.

Mažeikienė I., Juškytė A. D., Stanys V. 2019. Application of marker-assisted selection for resistance to gall mite and blackcurrant reversion virus in *Ribes* genus. Zemdirbyste-Agriculture, 106 (4): 359–366. https://doi.org/10.13080/z-a.2019.106.046

McMaster G. S., Wilhelm W. W. 1997. Growing degree-days: one equation, two interpretations. Agricultural and Forest Meteorology, 87 (4): 291–300. https://doi.org/10.1016/S0168-1923(97)00027-0

Pedersen L. H. 2007. Black- and red currants cultivars for low pesticide production. NJF 23rd Congress 2007. Trends and Perspectives in Agriculture, p. 188–189.

Pluta S., Pruski K. 2012. Suitability of fruits of selected black currant (*Ribes nigrum* L.) cultivars destined for fresh market. Journal of Berry Research, 2: 1–9. https://doi.org/10.3233/JBR-2011-025

Pluta S., Żurawicz E. 2014. 'Gofert' blackcurrant. HortScience, 49 (4): 513–515. https://doi.org/10.21273/HORTSCI.49.4.513

Rakonjac V., Djordjević B., Fotirić Akšić M., Vulić T., Djurović D. 2015. Estimation of variation and correlation analysis for yield components in black currant cultivars. Genetika, 47 (3): 785–794. https://doi.org/10.2298/GENSR1503785R

Sasnauskas A., Trajkovski V., Strautina S., Tikhonova O., Šikšnianas T., Rubinskiene M., Viškelis P., Lanauskas J., Valiuškaitė A., Rugienius R., Bobinas Č. 2009. Evaluation of blackcurrant cultivars and perspective hybrids in Lithuania. Agronomy Research, 7 (II): 737–743.

Sasnauskas A., Šikšnianas T., Stanys V., Viškelis P., Bobinaitė R., Rubinskienė M., Bobinas Č. 2013. Agronomical characters of introduced new blackcurrant cultivars. Proceedings of the Latvian Academy of Sciences, Section B: 67 (2): 211–214. https://doi.org/10.2478/prolas-2013-0036

Stanys V., Bendokas V., Rugienius R., Sasnauskas A., Frercks B., Mažeikienė I., Šikšnianas T. 2019. Management of anthocyanins amount and composition in genus *Ribes* using interspecific hybridisation. Scientia Horticulturae, 247: 123–129. https://doi.org/10.1016/j.scienta.2018.12.014

Strautiņa S., Lācis G., Kampuss K. 2020. Phenotypical variability and diversity within *Ribes* genetic resources collection of Latvia. Acta Horticulturae, 1277: 81–88. https://doi.org/10.17660/ActaHortic.2020.1277.11

Williams R. C., Baker D. R., Smith J. A. 1973. Analyses of water-soluble vitamins by high-speed ion-exchange chromatography. Journal of Chromatographic Science, 11: 618–624. https://doi.org/10.1093/chromsci/11.12.618

Woznicki T. L., Heide O. M., Sønsteby A., Wold A.-B., Remberg S. F. 2015. Yield and fruit quality of black currant (*Ribes nigrum* L.) are favoured by precipitation and cool summer conditions. Acta Agriculturae Scandinavica, Section B: Soil and Plant Science, 65 (8): 702–712. https://doi.org/10.1080/09064710.2015.1052093

Yang B., Zheng J., Kallio H. 2010. Compositional variation in fruits of currants as function of genotypes and their interactions with growth environments. NJF Report, 6 (2): 45.

Perspektyvių juodojo serbento hibridų biologinių, ekonominių ir biocheminių savybių įvertinimas Estijoje

A. Kikas, P. Laurson, A.-V. Libek

Estijos gyvybės mokslų universiteto Žemės ūkio ir aplinkos mokslų institutas

Santrauka

Juodojo serbento (*Ribes nigrum* L.) perspektyvių hibridų įvertinimas buvo atliktas 2016–2018 m. Pietų Estijoje, Estijos gyvybės mokslų universiteto Polli sodininkystės tyrimų centre. Estijos juodojo serbento selekcinės programos tikslas – išvesti šalčiui ir serbentinei erkutei (*Cecidophyopsis ribis* Westw.) bei agrastų miltligei (*Sphaerotheca mors-uvae* (Schw.) Berk.) atsparias veisles, tinkamas derliaus mašininiam nuėmimui ir pasižyminčias geru derlingumu bei uogų kokybe. Eksperimento laukelis buvo įrengtas 2014 m. rudenį. Buvo įvertinti juodojo serbento 24 perspektyvūs hibridai iš Estijos juodųjų serbentų selekcinės programos ir nauja estiška veislė 'Mairi' kaip standartinė. Nustatytos šios savybės: žydėjimo ir uogų nokimo pradžia (išreikšta aktyvių temperatūrų dienomis), atsparumas žiemojimui, ligoms ir kenkėjams (1–9 balų skalėje), uogų skaičius vienoje kekėje, derlius (kg iš vieno krūmo), uogų svoris ir tirpių kietųjų medžiagų kiekis (°Brix). Serbentų uogose tirta titruojamųjų rūgščių, askorbo rūgšties, antocianinų ir polifenolių kiekis. Tyrimo metu nustatyti geriausi juodojo serbento genotipai: Nr. 3-08-1 ('Ben Alder' × 'Titania'), 7-08-1, 7-08-2 ('Intercontinental' × 'Pamyat Vavilova') ir 15-09-1 ('Asker' – laisvai apsidulkinanti), žaliauogio serbento – Nr. 8-09-3 ('Öjebyn' × 'Mairi'). Šie genotipai yra atsparūs žiemojimui ir vizualiai atsparūs serbentinei erkutei bei agrastų miltligei. Pirmieji keturi genotipai davė gerą derlių ir užaugino dideles uogas.

Reikšminiai žodžiai: antraknozė, derlius, *Ribes nigrum* genotipai, uogų svoris, žiemkentiškumas.